From: A.Prof. Tran Van Lang
Sent: Tuesday, November 22, 2022 3:02 PM
To: Tu Vo Thanh; Le Huu Binh; Vu Phan Dinh Nguyen
Subject: [VJST] Editor Decision

Dear Tu Vo Thanh, Le Huu Binh, Vu Phan Dinh Nguyen,

Our referees have now considered your paper and have recommended publication in Vietnam Journal of Science and Technology.
We have reached a decision regarding your submission "DESTINATION SEQUENCED DISTANCE VECTOR ROUTING TAKING INTO ACCOUNT SIGNAL TO NOISE FOR FLYING AD HOC NETWORK" to Vietnam Journal of Science and Technology.
We are pleased to accept your paper in its current form which will be forwarded to the publisher for copy editing and typesetting in due course.

Thank you for your contribution to Vietnam Journal of Science and Technology, and we look forward to receiving further submissions from you.

Kind Regards,
Tran Van Lang, PhD. Section Editor
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DESTINATION SEQUENCED DISTANCE VECTOR ROUTING... 1 Published View

DESTINATION SEQUENCED DISTANCE VECTOR ROUTING TAKING INTO ACCOUNT SIGNAL TO NOISE FOR FLYING AD HOC NETWORK

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Abstract. Flying ad hoc network (FANET) is becoming more popular in both military and civilian applications. The primary characteristic of the FANET is high mobility, which results in a constantly changing topology. This is a significant challenge for protocols that control data transmission from nodes to base stations. As a result, many research groups have recently been attracted to the study of data transmission control protocols in FANET, typically routing protocols. This paper presents the application of the Destination Sequenced Distance Vector (DSDV) routing protocols for FANET. We improve the DSDV routing protocol by considering signal-to-noise ratio (SNR) when discovering new routes. The simulation results show that the improved DSDV algorithm outperforms the traditional DSDV algorithm in terms of network throughput, end-to-end delay and SNR.

Keywords: Flying ad hoc network, DSDV, SNR.

Classification numbers: 4.5.1, 4.5.2

1. INTRODUCTION

Unmanned aerial vehicles (UAVs) are becoming more modern and widely used in a variety of fields due to recent remarkable advancements in wireless communication technology and intelligent control systems. A multi-UAV system is much more efficient than a single UAV because it is suitable for multitasking applications, wide and complex terrain. In this case, the UAVs must connect and collaborate to form a network known as a UAV network or flying ad-hoc network (FANET). Figure 1 is an example of a FANET, where there are 13 UAVs and one base station (BS). The UAVs in each other's coverage area are connected to each other by a wireless link, forming a mesh topology. For the current state, U_1, U_6 and U_{10} are covered by the BS, they can transmit data directly to the BS. The other UAVs are not covered by the BS, they must go through some intermediate UAVs to transmit data to BS. For example, $U_4 \rightarrow U_8 \rightarrow U_5 \rightarrow U_1 \rightarrow$ BS is a route to transfer data from U_4 to BS.

Control protocols such as routing, switching, and signaling are used in FANET to transmit data between UAVs. However, effectively implementing these protocols is a major challenge due to the unique characteristics of UAVs, such as high mobility, sparse node density, and being heavily influenced by environmental noise. Therefore, the study of control protocols in FANET is a fascinating subject that has recently attracted the attention of numerous research groups, where routing is a key issue. In [1], the authors conducted a thorough analysis of the cluster-based routing protocols (CBRPs) for FANET, examining their strengths, drawbacks, particular applications, approach, cluster head selection, routing metrics and potential future improvements of CBRPs. The authors of [2] have studied the use of AODV, DSR, and DSDV protocols for FANET. The simulation method on NS-3 is used to compare the performance of these protocols in terms of network delay, traffic received, data dropped and throughput. The use of AODV and DSR routing protocols for FANET has also been studied in [4], where the authors used a highway mobility model to assess how well these routing protocols performed in the FANET environment. It can be concluded from experimental study utilizing NS-2 under constant bit rate (CBR) and TCP traffic sources that AODV performs better than DSR nearly in all respects. In [3], Optimized Link State Routing (OLSR) protocol is used for FANET. The authors investigated OLSR under various mobility models in order to improve OLSR performance in FANETs.

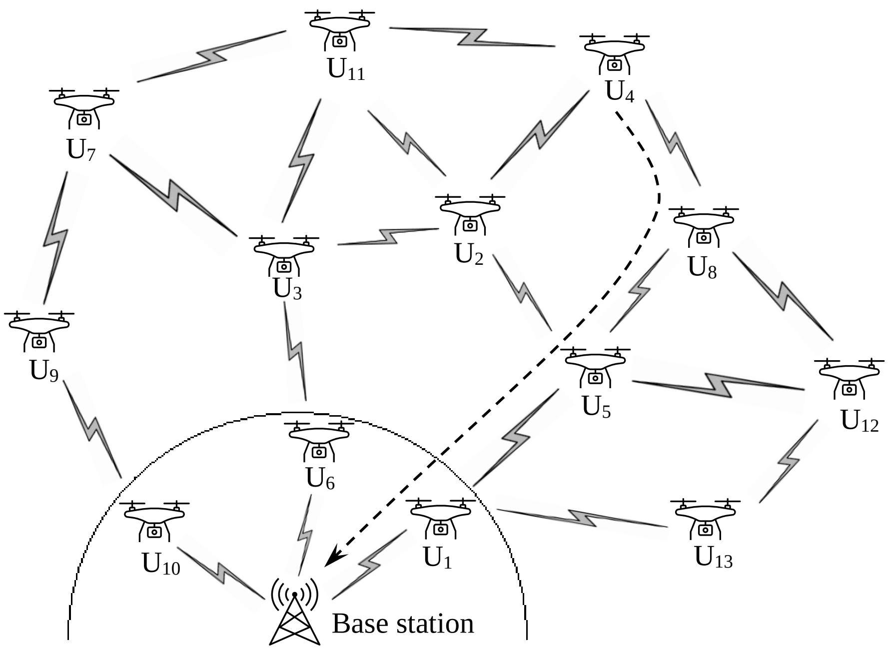

Figure 1. An example of flying ad-hoc network

Routing metric is another area of FANET routing that has recently piqued the interest of numerous research groups. The authors of [5] have investigated reliability-based routing metrics for UAV networks and have presented a metric that considers the relative speeds of UAVs. The AODV routing system with this metric becomes effective in high mobility scenarios, according to simulation results using NS-2. In [6], the authors proposed a routing metric namely I2R that takes into account inter-flow interference for flying multi-hop networks. When compared to the state-of-the-art routing metrics of Expected Transmission Count (ETX) [7] and some other metrics, simulation results demonstrate the I2R's improved performance, with appreciable benefits in throughput and end-to-end delay.

Routing metrics have a significant impact on routing protocol performance in the FANET environment. It is crucial to develop a routing statistic that takes link quality into account. In this study, we suggest a routing metric for the DSDV protocol in the FANET environment that accounts for both hop count and SNR. The next sections of this paper are organized as follows. Section 2 presents our proposed routing metric. Section 3 shows how to apply the new routing metric to the DSDV protocol in the FANET environment. Some simulation results and discussion are presented in section 4. Finally, concluding remarks and promising future study items are given in Section 5.

2. HOP COUNT AND SNR AWARE ROUTING METRIC (HCS)

2.1. SNR of a route in FANET

SNR is one of the crucial metrics to evaluate the effectiveness of data channels in communication networks, including wired and wireless networks, calculated by [8]

$$\beta = 10\log_{10}\left(\frac{P_s}{P_n}\right) \qquad (dB) \tag{1}$$

where P_s and P_n are the signal and noise powers, respectively. The higher the SNR of a data transmission channel, the lower the BER and the better the quality of transmission (QoT). As shown in Figure 2, we determined the theoretical curve of BER versus SNR for various modulation techniques by using BERtool in MATLAB software [9]. The modulation techniques considered are quadrature amplitude modulation (QAM), which includes 4-QAM, 16-QAM, 64-QAM, and 128-QAM. We can see that as the SNR rises, the BER falls exponentially. In the case of 128-QAM, for example, if SNR is 16 dB, BER is 1e-2. When SNR is increased to 20 dB and 24 dB, BER drops to 7e-5 and 3e-9, respectively.

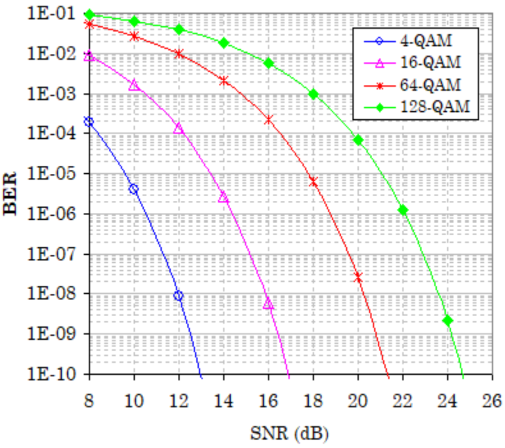

Figure 2. BER versus SNR characteristics for QAM modulation

When data is transferred over numerous intermediary nodes in the FANET, the noise power that accumulates along the route rises. The route's SNR declines as a result. The relay type of the intermediate nodes affects how the SNR declines. The intermediate nodes in a multi-hop wireless network have two options for data forwarding: amplify and forward (AF) or decode and forward (DF) [10], [11]. These forward kinds affect a route's SNR, which is calculated by

$$\beta_{s,d} = \begin{cases} \underset{\forall h_{i,j} \in r_{s,d}}{Min} (\beta_{i,j}) & \text{if } DF \\ \left(\sum_{\forall h_{ij} \in r_{sd}} \frac{1}{\beta_{i,j}} \right)^{-1} & \text{otherwise} \end{cases} \quad (2)$$

where $\beta_{s,d}$ and $\beta_{i,j}$ are the SNR of the route $r_{s,d}$ and the hop $h_{i,j}$, respectively.

2.2. HCS routing metric

Because nodes in FANET move frequently, the SNR of the links changes as well. Furthermore, the SNR difference between the connections is significant. As a result, hop-based routing is inefficient, as are traditional routing protocols. In this paper, we propose HSR, a routing metric for FANET that considers both hops and SNR, which is defined as follows:

$$w_{s,d} = \alpha \frac{\beta_{min}}{\beta_{s,d}} + (1-\alpha) \frac{h_{s,d}}{h_{max}} \quad (3)$$

where $w_{s,d}$ is the metric of the route r_{sd}, β_{min} is the minimum SNR of all links in FANET. $\beta_{s,d}$ is the SNR of the route $r_{s,d}$ which is determined according to (*2*). $h_{s,d}$ is the number of hops of the route $r_{s,d}$, h_{max} is the number of hops the longest route in the network. In a network topology, the longest route is the one that passes through all nodes, i.e. n - 1 hops with n is the number of nodes. Therefore, h_{max} is set to n - 1. α is a coefficient in the range [0, 1] which is used to control the effect degree of metrics SNR and hop count.

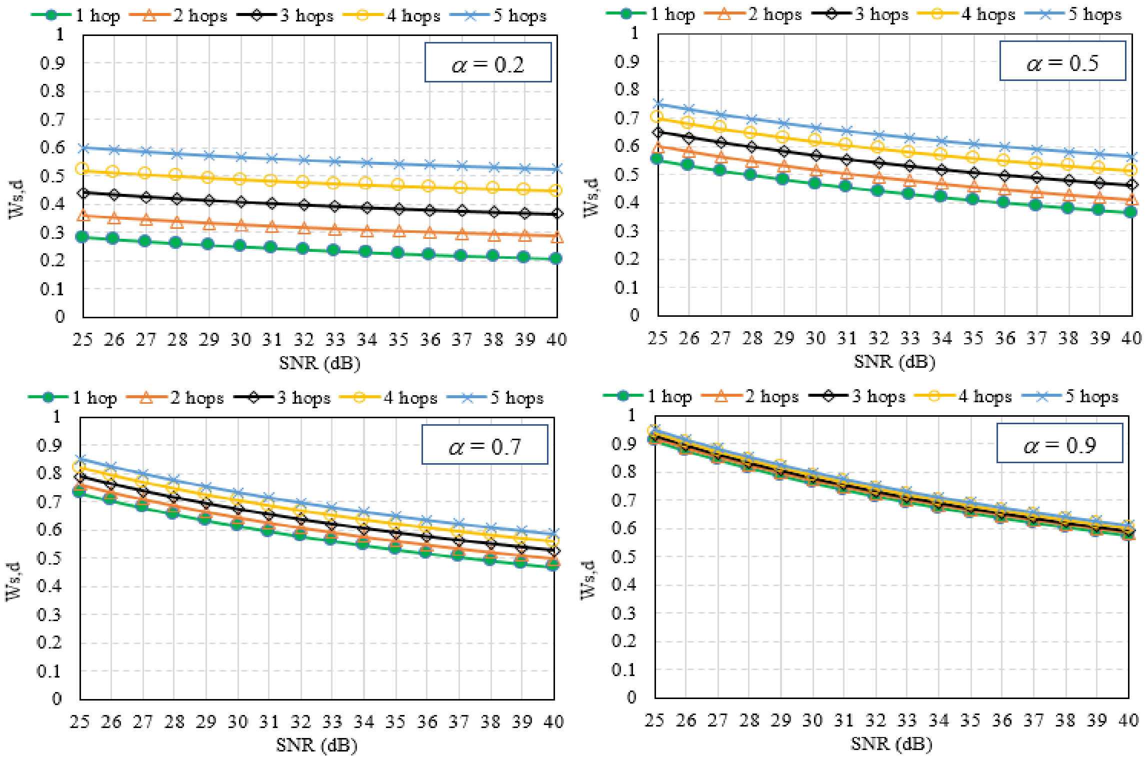

Figure 3. Impact of parameters SNR, hop count and coefficient α on the HCS metric

To clearly see the effect of SNR, hop count, and coefficient α on the HCS metric, consider a FANET with 20 nodes and the minimum SNR of 25 dB. Since the number of nodes is 20, $h_{\max}$ = 19. The results of the calculation of the HCS metric according to the SNR, hop count and α parameters are as shown in Figure 3. We can see that when α equals 0.2, $w_{s,d}$ is primarily determined by the number of hops and less by the SNR. When α is 0.5, $w_{s,d}$ is affected by both the SNR and the hop count parameters. When α is large (0.7 and 0.9), $w_{s,d}$ is primarily determined by the SNR, with little influence from the hop count. Because the goal of the HCS metric is to take into account both SNR and hop counts, we chose α to be 0.5.

4. DSDV-HCS ROUTING ALGORITHM FOR FANET

In this section, we demonstrate how to apply the proposed HCS metric to the DSDV routing protocol in the FANET environment. The DSDV protocol that employs the HCS metric is named DSDV-HCS.

Figure 4 depicts the hello packet processing process at each FANET node using the DSDV-HCS algorithm, where the meanings of the symbols are described as shown in Table 1. The DSDV-HCS algorithm differs from the original DSDV algorithm in that it computes the metric to update the routing table at each node whenever that node receives a hello packet. Because the DSDV algorithm routes based on hop count, every time a node broadcasts a hello packet to update routing information, the hop count is increased by one. The routing metric utilized by the DSDV-HCS method is SNR and hop count, therefore each time a node needs to update its routing table, it must calculate the SNR from it to the destination node.

Table 1. Description of the notation used for DSDV-HCS algorithm

Notation	Description
G_{hello}	The node that generates the hello packet
S_{hello}	The node that sends the hello packet
I	The node that receives the hello packet
w_{hello}	Metric from node S_{hello} to node G_{hello}
N_{rc}	Next node of a route in route cache (RC)
w_{rc}	Metric of a route in RC
$w_{I,S_{hello}}$	Metric of route from node I to node S_{hello}
seq_{hello}	Sequence number of a route in the hello packet
Seq_{rc}	Sequence number of a route in RC
$R_{I,G_{hello}}$	Route from node I to node G_{hello} in RC of node I

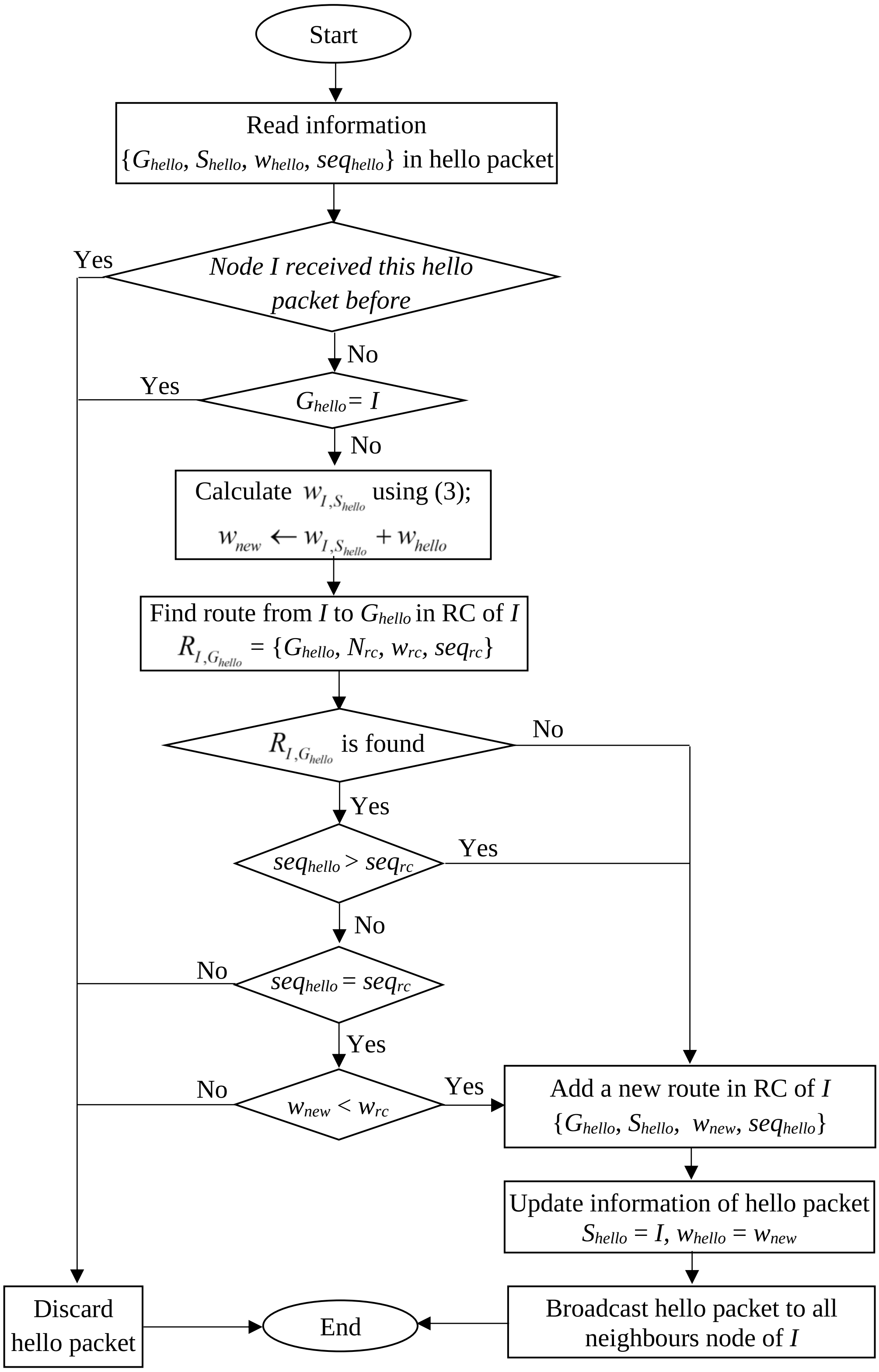

Figure 4. Flowchart of DSDV-HCS algorithm for FANET

4. PERFORMANCE EVALUATION BY SIMULATION

The performance of DSDV-HCS algorithm is evaluated by simulation method using OMNET++ [12] and INET Framework [13]. The DSDV-HCS algorithm is compared with the traditional DSDV algorithm in terms of network throughput, delay end-to-end and SNR. The simulation assumptions are presented in Table 2. Figure 5 shows A snapshot of the interface when running the FANET simulation.

Table 2. Simulation parameters

Notation	Description
Simulation area	1000 × 1000 × 1000 meters
Radio range	250 meters
Noise model	Thermal noise
Movement speed	5 - 30 mps
Mobility model	Mass mobility
Number of nodes	30
Number of base stations	1
Path loss model	Free space
Simulation time	2000 seconds

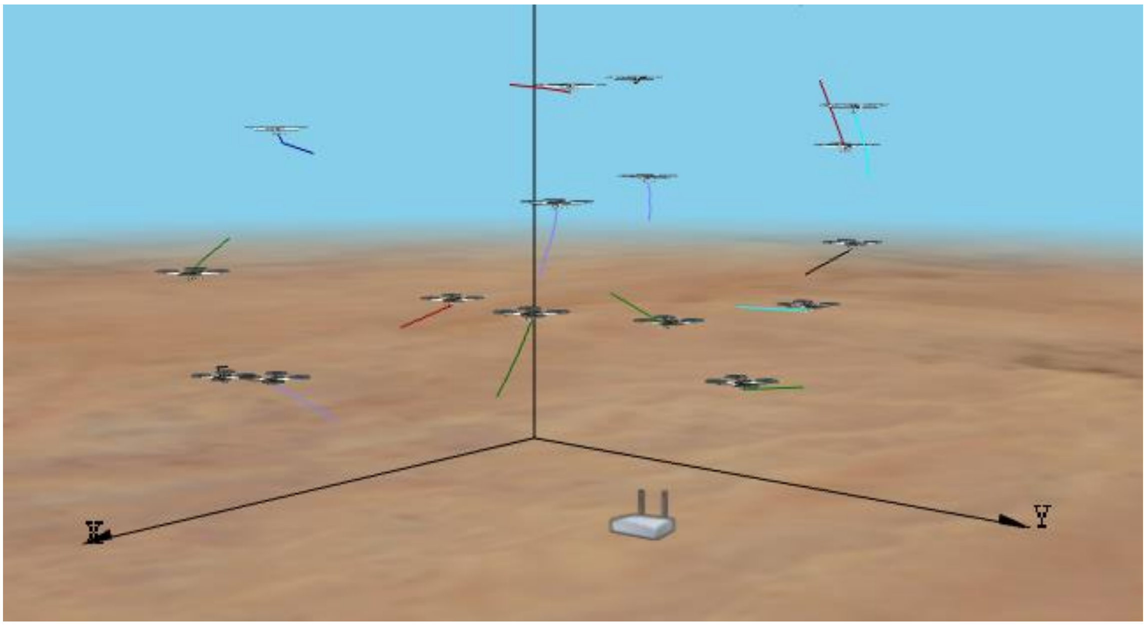

Figure 5. A snapshot of the interface when running the FANET simulation using OMNET++ and INET Framework

The results obtained in Figure 6 show the difference in the throughput received at the base station (BS) when using the DSDV and DSDV-HCS routing algorithms. In this case, the FANET nodes move at an average speed of 10 m/s. We can observe that, when the simulation time is less than 600 seconds, the throughput of both algorithms changes quite large because at this time the network is not stable. When the simulation time is greater than 600 seconds, the throughput of the two algorithms starts to stabilize with an average of about 120 Kbps and 100 Kbps for the DSDV-HCS and DSDV algorithms, respectively. Thus, algorithm DSDV-HCS outperforms algorithm DSDV in terms of throughput. When the nodes move at a higher speed, 15 m/s, the result is as shown in Figure 7. The average throughput of the DSDV and DSDV-HCS algorithms are 105 kbps and 112 kbps, respectively. Thus, the DSDV-HCS algorithm also provides higher throughput than the traditional DSDV algorithm.

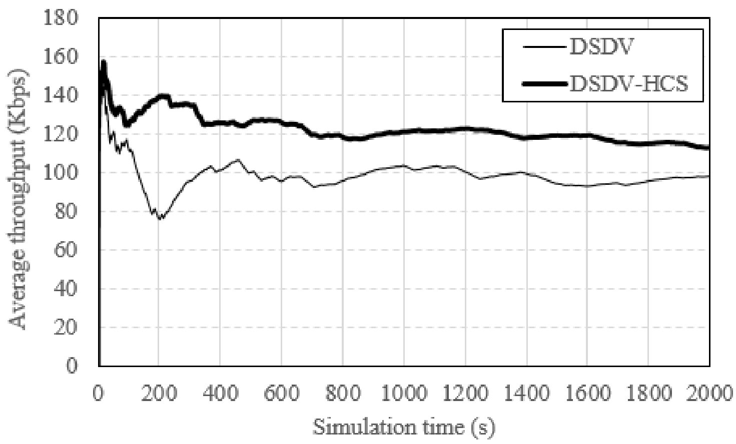

Figure 6. Compare the throughput of algorithm DSDV and DSDV-HCS in case the average moving speed of the nodes is 10 m/s

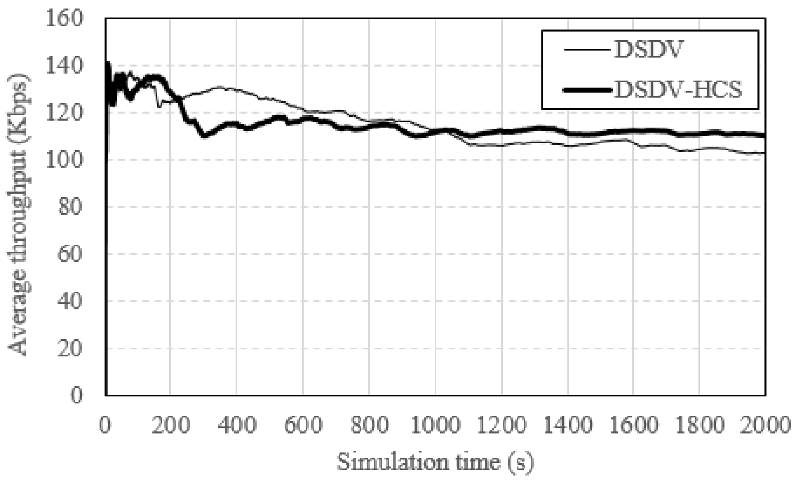

Figure 7. Compare the throughput of algorithm DSDV and DSDV-HCS in case the average moving speed of the nodes is 15 m/s

The dependence of the throughput on the movement speed of the nodes is clearly shown in Figure 7, where we plot the average received throughput at the BS as a function of mobility speed. We can observe that, when the travel speed of the nodes is less than 20 mps (equivalent to 27 kmps), the DSDV-HCS algorithm is more efficient than the DSDV algorithm. When the mobility speed is greater than 20 mps, the performance of both algorithms is similar. Thus, in terms of throughput, the DSDV-HCS algorithm is highly efficient when the moving speed of the nodes is moderate.

The findings of our analysis of the end-to-end delay are displayed in Figure 9. We can see that the DSDV-HCS algorithm always has a shorter end-to-end delay than the DSDV algorithm. The end-to-end delays of the DSDV-HCS and DSDV algorithms are 2.4 ms and 2.8 ms, respectively, when nodes are moving at a speed of 10 mps. In comparison to the DSDV algorithm, the DSDV-HCS algorithm can reduce end-to-end delay by a value of 0.4 ms. The end-to-end latency of the DSDV-HCS algorithm, with an average value of roughly 0.35 ms, is always smaller than that of the DSDV method for the other situations.

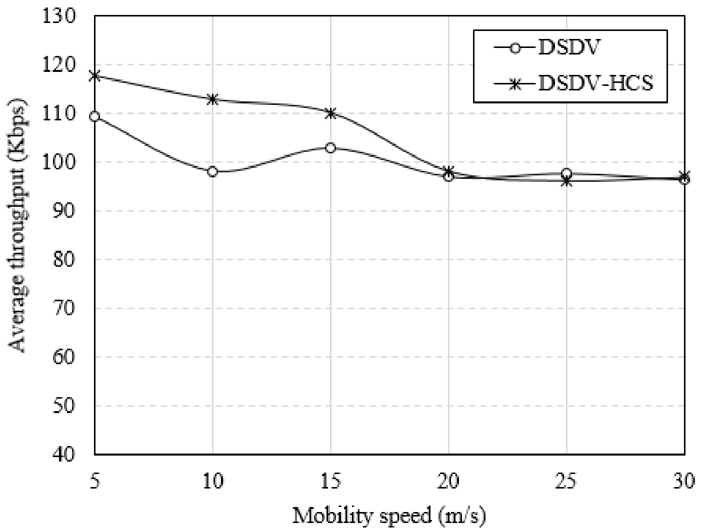

Figure 8. Compare the throughput of algorithm DSDV and DSDV-HCS versus mobility speed of nodes

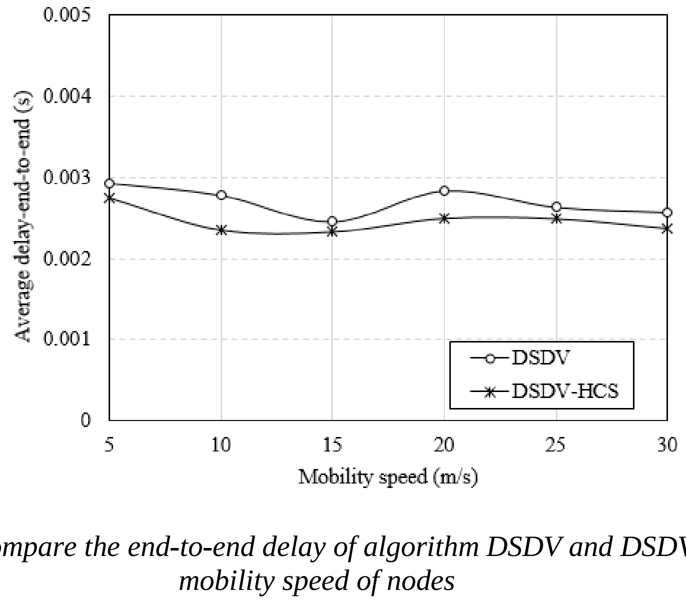

Figure 9. Compare the end-to-end delay of algorithm DSDV and DSDV-HCS versus mobility speed of nodes

Next, we analyze the SNR at the nodes. This is an important metric that greatly affects the quality of the data signal in the network. The histograms in Figure 10 show the smallest difference in SNR at all nodes. We can see that, the DSDV-HCS algorithm yields better SNR than the DSDV algorithm.

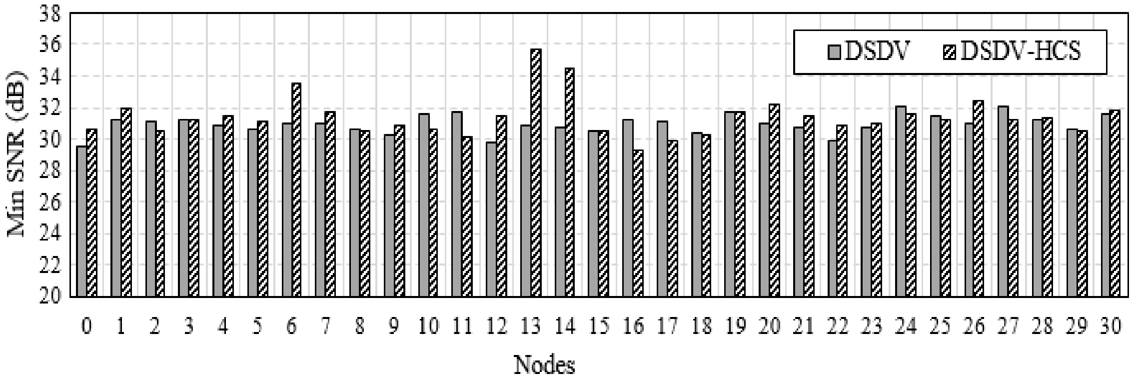

Figure 10. Compare the minimum SNR at the nodes of algorithm DSDV and DSDV-HCS

5. CONCLUSION

The use of flying ad hoc networks (FANET) in both military and non-military applications is growing. High mobility, the main feature of the FANET, leads to a topology that is continually changing. For protocols that regulate data transit from nodes to base stations, this presents a substantial difficulty. As a result, the study of data transmission control protocols in FANET, typically routing protocols, has recently attracted a lot of research groups. The application of the Destination Sequenced Distance Vector (DSDV) routing protocols for FANET is discussed in this work. By taking into account signal-to-noise ratio (SNR) when finding new routes, we enhance the DSDV routing protocol. The simulation results demonstrate that in terms of network throughput, end-to-end delay, and SNR, the revised DSDV algorithm performs better than the conventional DSDV algorithm.

In the next work, we will continue to improve this algorithm by introducing new constraints to increase the reliability of data transmission from nodes to base stations.

REFERENCES

[1] O. T. Abdulhae, J. S. Mandeep and M. Islam, "Cluster-Based Routing Protocols for Flying Ad Hoc Networks (FANETs)," in *IEEE Access*, vol. 10, pp. 32981-33004, 2022, doi: 10.1109/ACCESS.2022.3161446.

[2] Vijayakumar V, K. Mariyappan, N.Sivakumar and Sakthi Ganesh, "A performance analysis study of MANETs routing protocols in FANETs networks environments", *European Journal of Molecular & Clinical Medicine*, Vo. 7, No. 10, 2020, pp. 3007-3020.

[3] Singh, Kuldeep & Verma, Anil. (2014). Applying OLSR Routing in FANETs, *2014 IEEE International Conference on Advanced Communication Control and Computing Technologies (ICACCCT),* Ramanathapuram, Tamilnadu, INDIA, 2014, pp.1212-1215.

[4] Maakar, Sunil & Khurana, Manju & Chakraborty, Chinmay & Sinwar, Deepak & Srivastava, Durgesh, "Performance Evaluation of AODV and DSR Routing Protocols for Flying Ad hoc Network using Highway Mobility Model", *Journal of Circuits, Systems and Computers*. 2250008. 10.1142/S0218126622500086.

[5] Jasim, Musaab & Al-Qaysi, Hayder & Allbadi, Yousif & Musaab, Mohammed & Jasim, Musaab, "Reliability-based routing metric for UAVs networks", *Indonesian Journal of Electrical Engineering and Computer Science*, 21. 10.11591/ijeecs.v21.i, 2021, pp1771-1783.

[6] Coelho, Andre & Almeida, Eduardo & Ruela, José & Campos, Rui & Ricardo, Manuel, "A Routing Metric for Inter-flow Interference-aware Flying Multi-hop Networks", 2019, pp.1-6, 10.1109/ISCC47284.2019.8969575.

[7] D. S. De Couto, D. Aguayo, J. Bicket, and R. Morris, "A high-throughput path metric for multi-hop wireless routing," Wireless networks, vol. 11, no. 4, pp. 419–434, 2005.

[8] S. Srivastava and A. K. Daniel, "An Efficient Routing Protocol under Noisy Environment for Mobile Ad Hoc Networks using Fuzzy Logic," *Int. Journal of Advanced Research in Artificial Intelligence*, vol. 2, pp. 34-39, 2013.

[9] A. H.M.Mohamed and A. K.M. Ahmidat, "End To End Testing of Digital Transmission Systems Using Matlab," *American Journal of Engineering Research (AJER)*, vol. 6, no. 4, pp. 52–59, 2017.

[10] A.-S. K. Pathan, M. M. Monowar, and S. Khan, *Simulation Technologies in Networking and Communications - Selecting the Best Tool for the Test*, CRC Press, Taylor & Francis Group, LLC, 2015.

[11] S. Khan, A.-S. K. Pathan, and N. A. Alrajeh, *Wireless Sensor Networks - Current Status and Future Trends*, CRC Press, 2012.

[12] A. Varga, *OMNeT++ Discrete Event Simulation System*, Release 4.6, 2015.

[13] A. Virdis, M. Kirsche, *Recent Advances in Network Simulation The OMNeT++ Environment and its Ecosystem*, Springer Nature Switzerland AG, 2019.